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Moldy Rot of Tapping Panels of Hevea Rubbertrees¹

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THE observations and experiments reported in this circular were made from 1943 to 1947 at the Campo Experimental de Hule, at El Palmar, Veracruz, Mexico, in cooperation with the Mexican Department of Agriculture in a program to encourage the planting of hevea rubbertrees. In the vicinity of El Palmar, more than 30,000 old hevea rubbertrees have survived from seedling plantations started about 1910 and later abandoned. These trees were first tapped, beginning about 1939, by private individuals, and since then have been tapped intensively. Some 300,000 additional hevea rubbertrees,

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mostly budded with high-yielding oriental clones, have been set out since 1942 in field plantings in the El Palmar Valley as a result of the cooperative program.

The old hevea trees in the El Palmar Valley probably have been seriously affected with moldy rot since tapping began, for the writer observed heavy infection as early as 1943. At present, a high percentage are worthless as far as future commercial tapping is concerned, due primarily to moldy rot. The origin of the disease in the El Palmar plantings is unknown. The results of the studies and of experiments in its control are summarized as follows.

SUMMARY

Studies were made on moldy rot of the tapping panels of hevea rubbertrees in old plantations in southern Mexico from 1943 to 1947. The causal organism is indistinguishable morphologically from *Ceratostomella fimbriata*, which causes black rot of sweetpotato. Inoculation tests, however, have demonstrated that the hevea fungus does not cause black rot on sweetpotatoes. Considerable variation in cultural characteristics was observed among isolates of the *Ceratostomella* from rubbertrees, but no evidence of differences in pathogenicity was obtained in inoculation experiments with the hevea isolates on hevea trees. Typical moldy rot symptoms were not obtained with various other fungi isolated from diseased panels, but isolates of a *Fusarium* sp. were slightly pathogenic on injured hevea bark.

The moldy rot fungus develops rapidly on injured bark of *Hevea brasiliensis*. It soon rots the soft bark and cambial regions under conditions of high humidity, the principal environmental factor required for rapid development of the fungus on tapping panels. The fungus penetrates the bark above and below injured areas under some conditions, and it may be associated with a bark canker prevalent on the old hevea trees.

The damage caused by moldy rot is principally that of reducing the length of time trees can be tapped. In severe cases, tapping can be over original bark only, because sufficient renewed bark fails to occur to permit tapping over it.

Numerous fungicidal treatments were tried on the plantations of old diseased trees, most of them without other success than some reduction of the disease. The nearly ideal conditions for disease development in the old, poorly managed plantations may have accounted for the relatively poor success obtained with fungicidal treatments. The results of the present investigations on control measures, however, suggest that the most effective method of handling the disease, until further tests are made on fungicidal applications in more normal plantings, is to exclude the fungus from new plantings and to attempt to eradicate it from such plantings when first observed.

IMPORTANCE AND OCCURRENCE OF MOLDY ROT

Moldy rot, caused by *Ceratostomella fimbriata* (Ell. and Hals.) Elliott (*Endoconidiophora fimbriata* (Ell. and Hals.) Davidson), is a destructive disease of the tapping panels of hevea rubbertrees. Tap-

ping is the term applied to the process used for obtaining the latex from trees, and the tapping panel is that section of the tree trunk on which the bark is excised for that purpose. Tapping of hevea rubber-trees consists of excising the bark in the form of thin shavings at regular intervals to within about 1 mm. of the cambium. Although the latex vessels are mostly concentrated in the inner bark, it is necessary to leave the thin layer of bark to avoid wounding the cambium so that regeneration of the bark may occur. If there is no interference with bark renewal, tapping can be performed on the



FIGURE 1.—Tapping panel of a hevea rubbertree, showing lack of bark renewal on the lower half of panel tapped during a rainy season when moldy rot was widespread in the plantation. The bark on the upper part of the panel regenerated satisfactorily before the panel became infected.

regenerated bark within 5 to 7 years after the first tapping, and, under favorable conditions, again a third or fourth time in the succeeding years.

Freshly cut bark of hevea rubbertrees, however, is susceptible to attack by various fungi that infect and rot the bark and cambium and thereby prevent bark renewal on tapping panels. Under conditions favorable for the development of such fungi, the life and value of tapped rubbertrees may be reduced from 30 or more years to 10 or 15. *Ceratostomella fimbriata* is one of the most important of the fungi affecting tapping panels (17).³ A tapping panel affected with moldy rot is shown in figure 1.

Moldy rot was first recorded on hevea rubbertrees in Malaya in 1916 (1). It also occurs in Sumatra (5) and Java (8). According to

³ Italic numbers in parentheses refer to Literature Cited, p. 23.

Petch (13) and Beeley (1) it has not been recorded from Ceylon, where Beeley suggests seasonal changes of temperature and humidity do not favor the growth of the fungus as a parasite on rubber trees. Sharples (17) states that moldy rot has not been reported from Ceylon or India. Weir (20) does not report the disease from the Amazon Valley. The writer (12) found moldy rot quite prevalent in southern Mexico at El Palmar, Veracruz, and also at Las Palmas, Chiapas, and in Costa Rica on a few old seedling trees on a commercial estate at Cairo.

THE CAUSAL ORGANISM

HISTORY

Belgrave and de la Mare Norris (4) described a bark canker from Malaya in 1917 as "mouldy rot of recently tapped surface." They stated that inoculation experiments indicated that a species of *Sphaeronema* was the causal organism. In 1920 Sanderson and Sutcliffe (15) reported extensive inoculation experiments that definitely proved the organism to be *Sphaeronema* sp. Also in 1920, Sharples, Belgrave, de la Mare Norris, and Ellis (18) called the fungus *Sphaeronema fimbriata* (Ell. and Hals.) Sacc., which was the name applied at that time to the fungus causing black rot of sweetpotato. South (19) also referred to the fungus as *S. fimbriata*.

A brief history of the nomenclature of the sweetpotato black rot fungus will be of some value in clarifying the nomenclature of the moldy rot fungus. The black rot fungus was first called *Ceratocystis fimbriata* Ell. and Hals. by Halsted (9) from New Jersey in 1890, but he gave no technical description of the fungus. Later Saccardo (14) described the black rot organism and transferred it to the form genus *Sphaeronema*, after which it was known as *Sphaeronema fimbriata* (Ell. and Hals.) Sacc. It was known under this name until 1923, when Elliott (7) discovered that the fungus was an ascomycete of the Sphaeriales, with the peculiar characteristic of discharging its ascospores from the ascus inside the perithecium. After Elliott's discovery of the asci in the black rot organism, the proper designation of the fungus became *Ceratostomella fimbriata* (Ell. and Hals.) Elliott. More recently Davidson (6) placed the fungus in the genus *Endoconidiophora* on the basis of its formation of endoconidia. This arrangement would call for the name *Endoconidiophora fimbriata* (Ell. and Hals.) Davidson.

Beeley (1) states that the fungus causing moldy rot of tapping panels of hevea rubber trees and the fungus causing black rot of sweetpotato are alike morphologically and in cultural characteristics, although he did not observe asci in the fruiting bodies of the hevea fungus. He stated, however, that his inoculation experiments had shown that the rubber species would not attack living sweetpotato roots nor would the sweetpotato fungus attack living bark of hevea trees. Nevertheless, the fungus is referred to as *C. fimbriata* in the hevea literature (17).

In recent tests by the writer, inoculations made by dipping sweetpotatoes in a spore suspension of the hevea fungus failed to give black rot lesions. When sweetpotatoes were inoculated with sweetpotato cultures, however, typical black rot lesions appeared on the sweet-

potatoes within 10 days after inoculation. No experiments have been made in inoculating the bark of hevea trees with the sweet-potato fungus. It appears that the hevea fungus, however, should be considered a distinct form of *C. fimbriata*, in view of the fact that it is not pathogenic on sweetpotatoes.

MORPHOLOGY OF THE FUNGUS

The hevea fungus grows readily on culture media and produces the three typical spore forms described for *Ceratostomella fimbriata* (10), namely, hyaline conidia, olive-brown conidia, and hyaline ascospores. These spores are produced in culture as well as on the cortex of hevea trees. The writer observed no differences in morphological characters between isolates of the hevea fungus compared and isolates of the sweetpotato fungus. Asci were not observed in any of the fresh preparations of the hevea fungus nor in the sweetpotato fungus. No attempt was made to observe asci in either fungus.

SPORE GERMINATION

According to Sharples (17), germination of the spores of *Ceratostomella fimbriata* from hevea rubbertrees occurs freely only in nutrient solutions or culture media and hyaline endoconidia germinate within 24 hours after sowing. The germination of hyaline conidia was studied in the following: (1) Tap water; (2) 1- and 2-percent sucrose in tap water; (3) 1- and 2-percent dextrose in tap water; (4) potato extract in tap water; (5) hevea bark extract; and (6) hevea shoot extract in tap water. The plant extracts were made by macerating 1 gm. of the plant material in 10 cc. of water. Germination of the conidia was observed in hanging drops to which had been added conidia from a 10-day-old culture on malt-extract agar.

In the potato and hevea extracts, germination of the conidia was evident in the form of germ tubes about one-fourth the length of the conidia 1 hour after the conidia were sown. The germ tubes grew rapidly, and new conidia were being formed within 6 hours in these solutions.

In the solutions of dextrose and sucrose, germination did not start until 4 hours after the spores were sown. Growth of the germ tubes was much slower in these solutions than in the plant extracts.

In tap water there was no evidence of germination 6 hours after the spores were sown. After 12 hours, germ tubes were just starting to protrude in a small percentage of the spores. After 24 hours, the small number of spores that had germinated had only comparatively short germ tubes. In most cases a small oval conidium had formed at the end of the germ tube. This conidium developed thick walls after 48 to 72 hours. Such conidia were not produced in the plant extracts nor in the sugar solutions. These thick-walled spores, morphologically like the olive-brown conidia except for their hyaline appearance, germinated in a few cases when they were placed in a hevea bark extract. Mycelial growth and new conidia were formed within 24 hours.

VARIATION IN THE FUNGUS

Ordinary tissue isolations from infected material and from mass conidia on newly infected bark yielded cultures of the fungus that differed considerably in cultural characters when grown under comparable conditions on artificial culture media. Consequently, numerous single conidial and some 30 single ascospore cultures were made, and these were grown under comparable conditions in large test tubes and also in 125-cc. Erlenmeyer flasks on potato-dextrose agar. The isolates differed considerably in growth rate, production of perithecia and conidia, and in color of culture. Certain isolates consistently failed to produce perithecia on culture media; others produced relatively few; and some produced them in abundance.

The variation among isolates probably explains some of the confusing statements that have appeared in the literature concerning the production of perithecia (17). Sharples states that no perithecia were observed on infected panels over a period of years. This might be explained by the prevalence of only nonperithecial strains of the fungus, owing to environmental or other conditions during that particular time. Sharples (17, p. 218) also states that perithecia of *Ceratostomella fimbriata* from hevea trees did not appear in cultures until they were 3 to 4 weeks of age. In some of the writer's cultures, perithecia appeared within 6 days after transfers were made to potato-dextrose agar. Differences as to the time required for the formation of perithecia, however, were noted among isolates, some requiring 20 days or more before perithecia were formed. On naturally infected tapping panels at El Palmar, perithecia ordinarily were present, but in a few cases only conidia were found. In one case, isolations from a panel with only conidia yielded only conidial cultures that failed to produce perithecia even after 3 months in culture.

PATHOGENICITY

Sanderson and Sutcliffe (15) apparently were the first to make detailed studies on the pathogenicity of *Ceratostomella fimbriata* on hevea panels. They stated that inoculation of freshly exposed bark of hevea trees resulted in noticeable infection 24 hours later; that the infected surface rotted within 3 days; and later that the fungus penetrated the wood one-twelfth to one-eighth inch, spreading vertically through the wood fibers. They found other fungi, including *Cephalosporium* sp. and *Fusarium* sp., associated with the moldy rot fungus, but inoculation experiments with these gave negative results.

In the present studies, numerous isolations were made from diseased panels. In more than 50 percent of the cases in which isolations were made from newly diseased tissue, *C. fimbriata* was obtained. Other fungi also were isolated, including *Fusarium* sp., *Cephalosporium* sp., *Pestalotzia* sp., and others unidentified. Next to *C. fimbriata*, the fungus most commonly associated with diseased panels was *Fusarium* sp., and it also was the fungus most commonly found fruiting on the panels in association with *C. fimbriata*. Inoculations on cut bark of hevea rubber trees, with the various fungi isolated from the diseased panels, showed that *C. fimbriata* was very pathogenic and *Fusarium* sp. slightly. None of the other fungi isolated was pathogenic.

The method used for testing the isolates for pathogenicity on hevea bark was as follows: The bark on 3- or 4-year-old trees was sliced down to the soft bark area with a sharp knife. The soft bark on such trees was only about 1 mm. thick because the trees were growing in crowded nurseries. The mycelium and conidia of the fungus to be tested were applied to the soft bark, and a pad of moist cotton was placed over the injured bark to insure sufficient moisture (see fig. 5). Examinations were made by slicing thin sections of the soft bark where inoculations had been made and observing these sections for discoloration or abnormal appearance. Examinations were made 10 to 15 days after inoculation. In the case of nonpathogenic isolates, the bark ordinarily had corked over to some extent and showed no evidence of discoloration on sectioning. Isolates of *C. fimbriata* used in inoculations produced discoloration down to the cambium and into the wood. Figure 2 shows two trees—one inoculated with *C. fimbriata* and the other uninoculated—before and after removing the layer of soft bark.

The results 1 year after inoculation with *C. fimbriata* in the soft bark area compared with the uninoculated control are shown in figure 3. In the inoculated tree, the bark had been killed and the wood had started to rot. Wood borers and termites invade such wounds on hevea trees, and quite often trees suffer wind breakage at these points. In the uninoculated control, bark renewal had occurred and there was little noticeable effect of the injury produced by slicing the bark down to the soft bark area 1 year previously.

No differences in pathogenicity were noted among many mass and many single-spore isolates of the fungus. Conidial and perithecial strains were equally pathogenic.

HOST-PARASITE RELATIONS

RATE OF DEVELOPMENT OF THE FUNGUS ON THE HOST

Sharpley (17, p. 211) states:

In three to four weeks after infection the diseased tissues rot completely, exposing diseased and discolored wood and forming wounds similar to those produced by bad tapping. . . . Penetration of the wood is slight and wood discoloration is rarely found at a depth exceeding $\frac{1}{4}$ inch. It may be greenish-black in color. The fungus has never been found to penetrate below the tapping cut, although narrow dark hair lines may run in the wood above and below the cut.

The observations made by the writer differ considerably from those of Sharpley. Studies were made of the progress of infection by inoculating 4-year-old trees with conidial suspensions atomized on the soft bark area after the hard bark had been sliced off. The inoculated areas were covered with pads of moist cotton (see fig. 5). To determine the time required for the fungus to penetrate through the soft bark (approximately 1 mm. thick), the bark on different trees was peeled down to the cambial region in the inoculated areas on successive days after inoculation. The following observations were recorded on the inoculated areas:

(1) A small, grayish growth containing newly formed conidia was evident on the surface within 24 hours after inoculation.

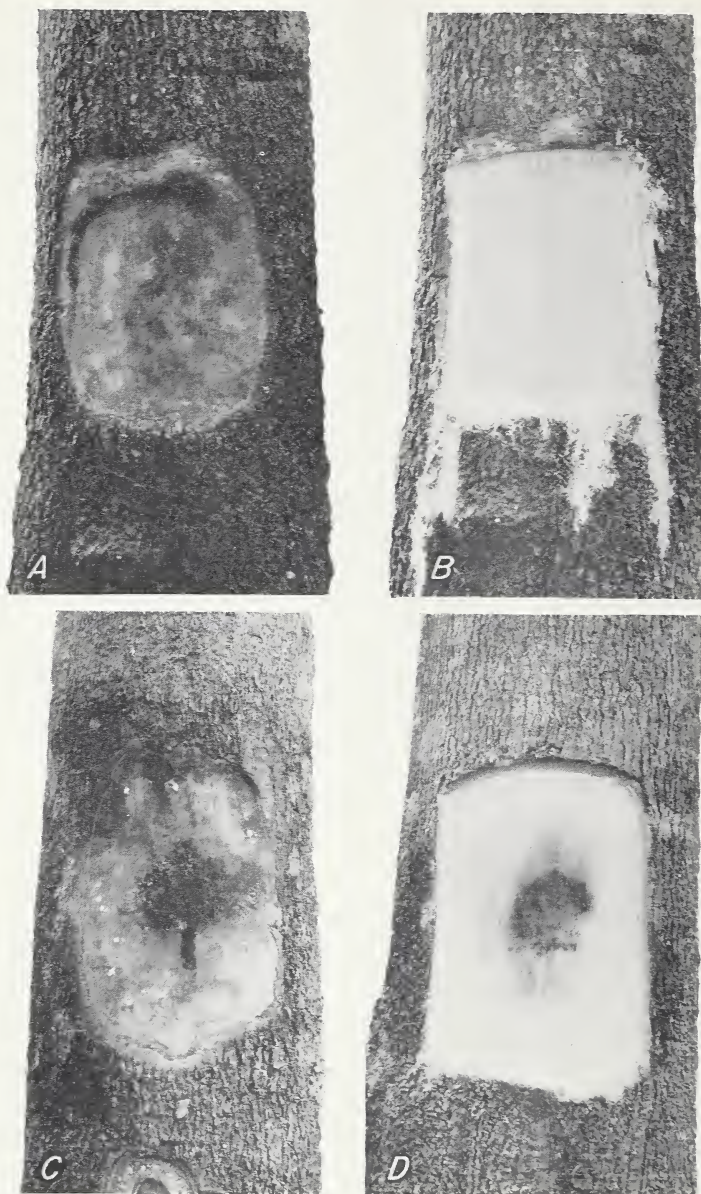


FIGURE 2.—Four-year-old trees of *Hevea brasiliensis* 7 days after the hard bark had been sliced off. A. Uninoculated control, showing a superficial growth of saprophytic fungi. B. Same tree as in A, with soft bark removed, exposing the sound cambial region. C. Tree inoculated by smearing conidia of *Ceratostomella fimbriata* over the central part, showing the rotting of bark in the inoculated area. D. Same tree as in C, with soft bark removed, exposing the diseased cambial region. Penetration had occurred through the soft bark and into the wood by the end of the seventh day after inoculation.

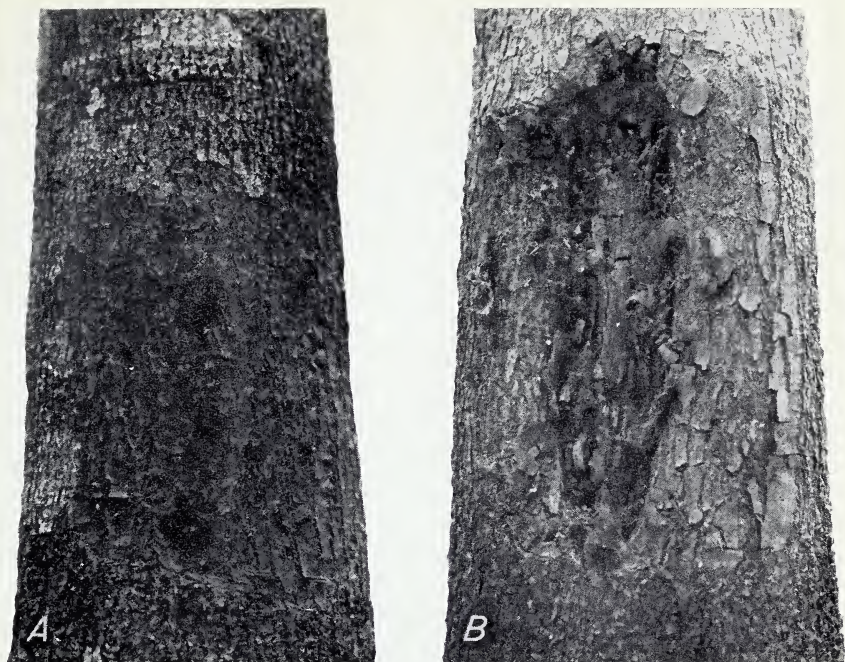


FIGURE 3.—Four-year-old seedling trees of *Hevea brasiliensis* 1 year after the bark was sliced down to the soft bark area: A, Uninoculated control, showing normal bark renewal; B, tree inoculated with spores of *Ceratostomella fimbriata* at the time the bark was sliced off, showing lack of bark renewal and rotting of the wood.

(2) Considerable mycelial growth and an abundance of conidia had formed in 48 hours.

(3) Perithecia had formed in abundance and small spore masses were present on the tips of the perithecial necks within 72 hours.

(4) Macroscopically visible evidence of penetration to the cambial region was observed within 4 days. The fungus was isolated in pure culture from the cambial region by making tissue transfers from that region.

(5) The bark next to the cambial region was discolored and in the process of decay within 7 days, and the fungus had penetrated as much as 2 mm. into the wood.

SUSCEPTIBILITY TO FUNGUS OF HARD AND SOFT BARK

To determine the relative susceptibility of the hard and soft bark areas, inoculations were made by atomizing conidial suspensions on the outer bark, which had been scraped down to the living cells, and making comparable inoculations on the soft bark, as previously described. The fungus penetrated and developed more slowly on the hard than on the soft bark. Penetration from the soft bark area had reached the cambium over all the surface inoculated within 8 days, while penetration from the hard bark had reached the cambial region in only a few isolated spots. In the trees used for these tests, the thickness of the hard bark area was from 2 to 3 mm., whereas that of the soft bark was approximately 1 mm. These trees were old nursery seedlings growing under crowded conditions.

PENETRATION OF THE FUNGUS BELOW THE TAPPING CUT

Observations were made in 1945 on the panels of trees affected with moldy rot for the purpose of determining the depth of penetration by the fungus below the tapping cut, or, in other words, below the injured bark. Various cases of discoloration typical of that caused by *Ceratostomella fimbriata* were noted below the tapping cut, mostly within one-half inch of the cut, but a few were 6 inches below it. The discolorations were mostly in the soft bark area next to the cambium. To determine whether the fungus could be isolated from these discolored areas, tissue transfers from these areas were made to test tubes of culture media. These results, given in table 1, indicate that the statements in the literature to the effect that the fungus does not penetrate below the tapping cut must be questioned.

TABLE 1.—*Results of isolation from discolored areas below the tapping cuts on panels of trees affected with Ceratostomella fimbriata*

Depth below tapping cut (inches)	Cases investigated	Cases yielding <i>C. fimbriata</i> upon isolation	Depth below tapping cut (inches)	Cases investigated	Cases yielding <i>C. fimbriata</i> upon isolation
	Number	Number		Number	Number
6-----	3	2	1-----	3	3
4-----	3	3	1/2-----	7	6
3-----	5	2	1/4-----	11	11
2-----	4	2			

Further studies were made to determine the depth of penetration by the fungus below the injured bark. Inoculations were made on 4-year-old trees in the following manner: An area of bark 3 by 6 inches was scraped down to the soft bark area on each tree, and a conidial suspension was sprayed over all the injured area. Examinations were made 10 days after inoculation by cutting the bark in thin slices above and below the inoculated area, tracing the discoloration produced by the fungus. In 20 cases penetration below the injured area was more than half an inch; in 4 cases, more than 4 inches; and in 1 case, approximately 6 inches. The spread of the fungus was in a vertical direction and mostly in the soft bark next to the cambial region. No appreciable horizontal spread of the fungus was observed, as shown in figure 4.

INJURY OF THE BARK IN RELATION TO INFECTION

Numerous inoculations were made with spores of *Ceratostomella fimbriata* on uninjured bark of 4-year-old hevea trees, but no infection was obtained. At least a slight injury, as that produced by scraping the bark lightly with a knife, was required for infection.

Experiments were made to determine the effect on subsequent infection of the time between injury and inoculation. Inoculations were made immediately after scraping the bark down to the soft bark area and at intervals of 6, 15, 44, and 70 hours. A pad of moist cotton was placed over the inoculated areas to insure sufficient mois-

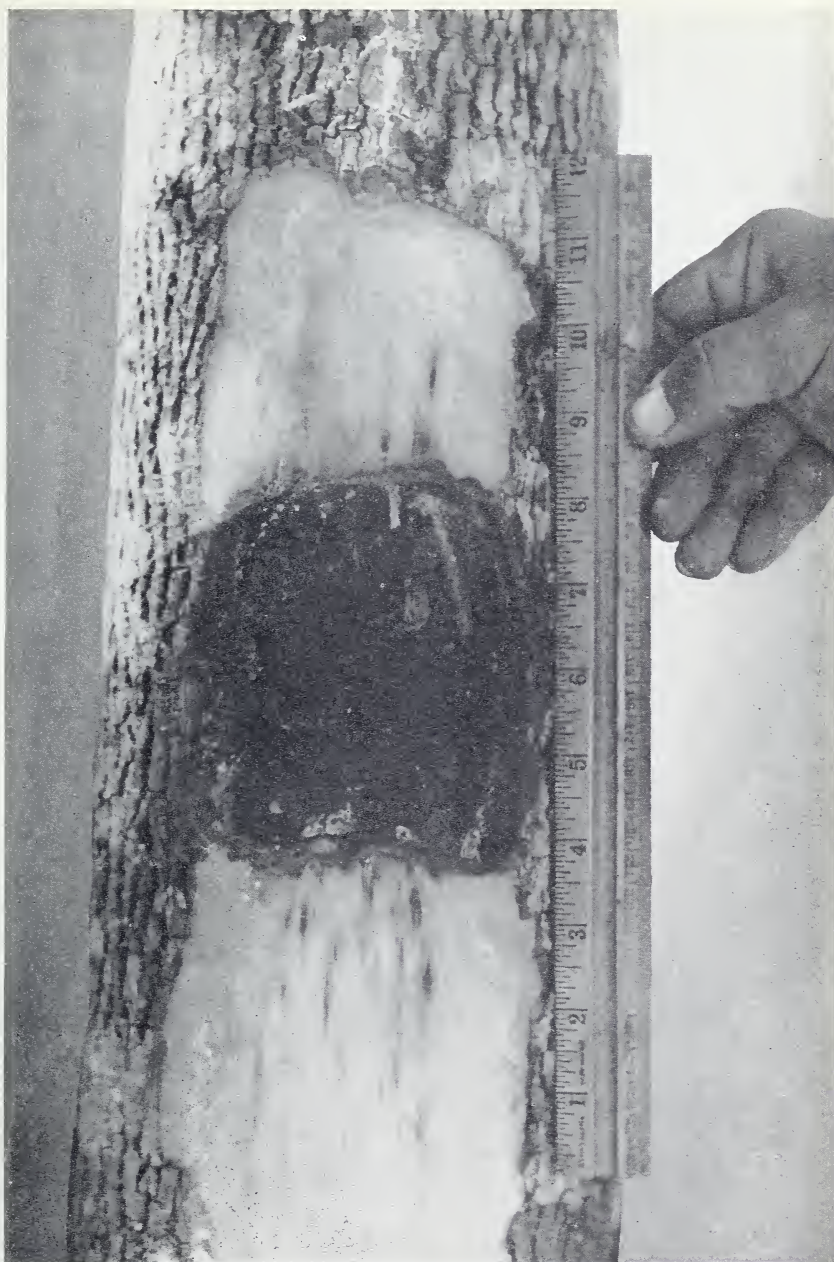


FIGURE 4.—A 4-year-old hevea rubber tree, showing spread of the fungus from the inoculated area. To trace the spread, the bark was sliced down to the soft bark and inoculated with *Ceratostomella fimbriata*, and later the bark was sliced back above and below the point of inoculation. The fungus had penetrated 4 inches below the point of inoculation in 10 days.

ture to permit infection. The results of these tests showed that infection occurred as readily on the areas inoculated 6, 15, and 44 hours after injury as on areas inoculated immediately after injury. These areas were all uniformly infected to the cambium within 12 days. The areas inoculated 70 hours after injury showed considerably less infection, but small points of infection extended to the cambium. These results indicate that corking-over of the injured bark is insufficient, even after 3 days, to prevent infection if other conditions of inoculum and environment are favorable.

ENVIRONMENTAL CONDITIONS

EFFECT OF MOISTURE ON DISEASE DEVELOPMENT

The necessity of high moisture for infection and development of *Ceratosomella fimbriata* on hevea panels has been stressed in the literature (1, 3, 4, 11, 15, 17, 19). The writer's observations and experiments support assertions that high humidity is necessary for infection to occur and for subsequent development of the fungus in and on the bark. It should be pointed out, however, that after a panel is infected it might remain infected even under rather severe drought conditions. While it is true that sporulation will not occur under such conditions and the area that is tapped during dry periods will consequently appear to be free from infection, the mycelium quite often found in the bark next to the cambium causes a greenish-black discoloration. Moreover, the fungus grows very slowly in the bark during dry periods and, in many cases, the trees become free from infection. Apparently the fungus cannot grow rapidly enough in such cases to keep up with the tapping, and bark renewal occurs over the areas tapped during the dry periods (fig. 1).

Under conditions at El Palmar, however, where there is a rather pronounced dry period lasting approximately 3 months, the fungus could be found in the bark on tapping panels of some trees at almost all times throughout the dry season. At the beginning of the rainy season, such trees produced a mycelial and conidial flush in isolated spots along the tapping cut within 24 hours after the first rain. Thus, it was not surprising to find practically all the trees with infections on the panels shortly after the beginning of the rainy season.

In most of the inoculation tests, the pad of moist cotton to furnish moisture was placed over the inoculated areas at the time the inoculations were made, as illustrated in figure 5. During rainy, misty periods infection was as good without the moist pads as with them.

During the dry season of 1947, experiments were conducted to study moisture relations and their effect on infection of hevea bark by *C. fimbriata*. Inoculations were made on the soft bark area of 4-year-old trees by spraying a conidial suspension over the prepared areas, approximately 3 by 6 inches in size. The inoculated areas were on the north side of the tree and not exposed directly to the sun. Each of six treatments was given to four inoculated areas. The inoculated areas in treatment 1 were left exposed. In treatment 2, moist pads of cotton were applied immediately after inoculation, and in treatments 3, 4, 5, and 6 the moist pads were later applied, at intervals of 6, 10, 24, and 36 hours, respectively. Notes as to the extent and progress of infection were taken over a period of 7 days



FIGURE 5.—Four-year-old seedling trees of *Hevea brasiliensis*, showing the method used in inoculations with *Ceratostomella fimbriata*.

after inoculation. There was no rain and the atmosphere was dry for a period of 72 hours after inoculations were made.

No visible growth occurred on the inoculated areas in treatment 1 until after a light rain 72 hours after the experiment began. Within 24 hours after the rain, however, a few small spots of mycelial growth had developed, and these infected areas were rotted to the cambium by the seventh day. In treatment 2, mycelial development was abundant 24 hours after inoculation and the bark over all the inoculated area was rotted to the cambium by the seventh day. In treatments 3, 4, 5, and 6 no visible growth of the fungus was observed until after the application of the moist pads. Mycelial growth was abundant in all cases 24 hours after the moist pads were applied, and the bark was thoroughly infected down to the cambium by the seventh day after the experiment was begun.

Subsequent tests revealed that no appreciable development of the fungus occurs on inoculated areas during dry periods unless moisture is supplied for a period of at least 12 hours. Areas inoculated and left exposed under dry conditions for more than 6 days failed to become infected when moist pads were applied. A relatively few spots of infection were obtained when moisture was supplied on the sixth day after inoculation under such conditions. Thus it appears that under dry conditions conidia may remain viable as long as 6 days without apparent development on injured bark of hevea trees.

OTHER FACTORS AFFECTING DISEASE DEVELOPMENT

Other factors that affect infection and disease development on the tapping panels are mentioned in the literature on moldy rot (1, 3, 11, 17). These include such conditions as density of planting, shade and ventilation in the planting, and other factors indirectly related to moisture and humidity. Another factor that other investigators consider is depth of tapping. While deep tapping favors the development of the disease, it is the writer's opinion, from observations of many diseased panels, that once a panel becomes infected and moisture conditions are favorable the disease will progress regardless of whether tapping is deep or shallow. It is true that the fungus develops more rapidly on soft bark than on hard bark, but it is also true that the latex vessels are mostly in the soft bark area; consequently, tapping must be carried out in this area if adequate yields are to be obtained.

INSECTS FOLLOWING MOLDY ROT DAMAGE

After the bark is destroyed on a tapping panel, wood-rotting fungi almost invariably invade the diseased panel and the wood rotters are followed by a variety of insects, including termites and wood borers. The large larvae of a Diptera (*Pantophthalmus tabaninus* Thunberg)⁴ were particularly common following moldy rot damage to trees at El Palmar. Other smaller wood borers also were common. Trees invaded by wood-rotting fungi and borers following moldy rot damage are susceptible to wind breakage.

DISEASE CONTROL

HISTORY

Sharples (17) discusses the history of research on moldy rot control in detail. Attempts to control the disease by the use of fungicides on the tapping panels date back to 1917, shortly after moldy rot was first described. Applications of water-miscible coal tar emulsions were recommended in the Orient (16), and details were worked out by Beeley (2) for testing such fungicides. Heubel (11) emphasized in 1940 the fact that the methods of control then developed were not entirely satisfactory.

FIELD EXPERIMENTS ON INFECTED TREES

Experimental treatments of tapping panels affected with moldy rot were begun at El Palmar in 1944, using coal tar-asphalt-Diesel oil mixtures.^{5 6} Investigators in the Orient had reported the successful

⁴ Identified by Charles T. Greene, Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

⁵ The asphalt was Ennjay Oxidized Asphalt 180/200 MP, Formula No. 6520, and the coal tar was a refined product. Both were obtained from a company in the United States. Later, Asphalt No. 10 and coal tar from Petroleos Mexicanos were used.

⁶ The Department of Agriculture does not guarantee or warrant the standard of any product used herein. The trade names are supplied only for the purposes of information in order to report factually on available data and are not intended to be approved to the exclusion of other products that may be suitable.

treatment of moldy rot by painting diseased panels with such mixtures (5, 17). The experimental area in Mexico consisted of approximately 1,000 badly infected old seedling trees. The following two mixtures were used.

Mixture No. 1: 5 pounds of asphalt that was heated until it melted, allowed to cool for 20 minutes, and then thoroughly mixed with 5 pounds of Diesel oil.

Mixture No. 2: $7\frac{1}{2}$ pounds of coal tar, $1\frac{1}{4}$ pounds of asphalt, and $1\frac{1}{4}$ pounds of Diesel oil. The asphalt was heated until it melted and after it cooled for 20 minutes the Diesel oil was added and the mixture stirred thoroughly. The hot asphalt-Diesel oil was then added to the hot coal tar and mixed thoroughly.

Tests for burning of the hard and soft bark were made with the mixtures on 3-year-old trees, and considerable injury was noted. Treatments were begun on the badly infected old trees late in June 1944. The mixtures were applied with a paint brush over all the tapping panel at about 10-day intervals. No noticeable control was obtained, and treatments therefore were given at weekly intervals. Later, applications were made after each tapping. Although this considerably reduced the moldy rot on the panel, no bark renewal was obtained because of the severe burning that resulted from the treatment and the fact that the fungus was still present in the bark. The mixtures were difficult to apply, and their application required considerable labor. These factors would have reduced the likelihood of general use of the mixtures by rubber growers of small acreages, even had the treatments been of value in controlling the disease. Another way in which the general application of control measures would have been affected by utilizing these substances for treating tapping panels was through the loss of the scrap rubber⁷ after each application.

Experimental applications of coal tar-asphalt mixtures were continued in 1945 and 1946, using solar oil instead of Diesel oil, but the results continued to indicate that the coal tar-asphalt mixtures were of little or no value in controlling moldy rot.

In 1945 fungicides used in tests for controlling moldy rot included Hycol—a water-miscible coal-tar emulsion; Santobrite (sodium pentachlorophenate); Isothan Q-15 and Isothan Q-63; Spergon; and coal tar-asphalt-solar oil mixtures. Experiments were made to determine the injury caused to the bark by applying different concentrations of these fungicides on newly cut soft bark of 4-year-old hevea trees. No apparent injury was noted with Spergon, 4 percent; Isothan Q-15, 3 percent; Isothan Q-63, 5 percent; and Hycol, 4 percent. These concentrations were considerably higher in the case of the fungicides listed than that required to prevent growth of the fungus under laboratory conditions. Injury was great with 1 percent Santobrite, however, and considerable with 0.1 percent, but no injury was noted with 0.02 percent. Noticeable injury was noted with the coal-tar mixture, but fair bark renewal occurred on the young nondiseased trees after this had been applied to the soft bark area.

⁷ By scrap rubber is meant the rubber that collects in the tapping channel after the latex stops flowing. This is usually stripped off the panel just before tapping and is collected for lower grade rubber.

In September 1945, the eight treatments recorded in table 2 were made on diseased panels. All the trees in the experimental area were affected when the test began. The trees were being tapped alternate-daily, and the panels were treated on days when the trees were not tapped. The fungicides were applied with a brush and the panels were thoroughly wetted with the materials.

Relatively little or no control of moldy rot was observed as the treatments progressed. A summary of the notes taken 1 month after treatments began is given in table 2. Although the number of infected trees was not greatly affected by the treatments, a slight reduction in the fungus growth on the panels was noted in the case of the treated panels.

TABLE 2.—*Summary of the number of trees showing moldy rot on panels 1 month after treatment with fungicides*

Treatment	Trees with panels showing—		Infected 1 month later
	Moldy rot	No moldy rot	
	Number	Number	Percent
Hycol, 1 percent.....	82	3	94
Hycol, 2 percent.....	114	11	90
Spergon, 4 pounds per 100 gallons.....	269	2	99
Coal-tar mixture.....	84	1	99
Santobrite, 0.02 percent.....	76	1	99
Isothan Q-63, 3 percent.....	81	0	100
Isothan Q-15, 1 percent.....	81	0	100
Control.....	255	0	100

Heubel (11) discusses the use of fungicidal pastes for the control of moldy rot. Experimental treatment of diseased tapping panels with such materials was begun at El Palmar in 1945. Pastes were made up with mixtures of yellow petroleum jelly, paraffin, solar oil, and a fungicidal material. The following fungicides were used in pastes: Spergon, phenol, cresillic acid, Hycol, Arasan, and Carbolineo (a coal-tar compound obtained in Mexico). The pastes were tested for injury by applying them to the soft bark area of 4-year-old trees. It was found that the following concentrations of these fungicides in pastes did not cause appreciable injury to the soft bark of hevea: Spergon, 5 percent; phenol, 1; cresillic acid, 0.5; Hycol, 3; Arasan, 1; and Carbolineo, 3.

Spergon and Hycol were used in tests on diseased panels in the following mixtures, which proved to be of about the right consistency for easy application with a brush:

Mixture 1:

Yellow petroleum jelly.....	1,000 gm.
Paraffin.....	750 gm.
Solar oil.....	4,000 cc.
Spergon.....	300 gm.

Mixture 2:

Yellow petroleum jelly-----	1,000 gm.
Paraffin-----	750 gm.
Solar oil-----	2,250 cc.
Hycol-----	115 cc.

The pastes were made up by heating the petroleum jelly and paraffin to melting, adding the solar oil and the fungicide, and mixing thoroughly. In the case of Spergon paste, it was necessary to stir the mixture at frequent intervals while it cooled to a paste, to insure an even distribution of the Spergon, which would otherwise settle to the bottom while the material was still liquid.

The pastes were applied during December 1945 to badly diseased tapping panels. The first application was a thin coating of the paste over the affected part. Subsequent applications were made at weekly intervals over the area that had been tapped since the previous application. The use of Hycol paste was discontinued after the first two applications when growth of *Ceratostomella* was observed over the thin layer of paste.

Considerable reduction in the moldy rot was observed on the panels treated with Spergon paste after the first application, and after three applications very few panels showed heavy infection. The applications were discontinued in January 1946, when moldy rot was not developing on the panels because of dry weather.

Bark renewal on the treated panels was compared with the renewal on untreated panels. Fair bark renewal occurred on the surface that had been tapped during December 1945 on the treated panels; no bark renewal occurred on the untreated panels, because the bark and cambium on the surface tapped during that month were killed completely by the moldy rot fungus.

Applications of the Spergon paste were resumed with the beginning of the rainy season in June 1946 and were continued until November. About 1,000 trees were treated at approximately weekly intervals. During the very wet period in July and August, considerable moldy rot developed even on the treated panels, but quite noticeably less so than on those untreated. Bark renewal on the treated panels was good until the owner of the trees started very deep tapping about August 1 as a countermeasure to the greatly reduced price that he obtained for his rubber.

Tapping was down to the cambium in most cases, and bark renewal would have been poor under the best conditions. When deep tapping began, moldy rot increased rapidly, and within 2 weeks all the treated panels were badly infected. The moldy rot could not be reduced even with two applications a week.

The approximate cost of making up 18.5 liters of paste in May 1946, was as follows:

Petroleum jelly (4 kg. at \$0.15 per kg.)-----	\$0. 60
Paraffin (3 kg. at \$0.40 per kg.)-----	1. 20
Solar oil (16 l. at \$0.10 per l.)-----	1. 60
Spergon (1,200 gm.)-----Approximately--	3.00

Total, in United States currency----Approximately-- 6. 40

About 55 liters of paste were used in the applications from June through August 1946, on approximately 1,000 trees. Thus the cost

of the material per hectare (with 240 trees per hectare) was approximately \$4.60 (United States currency). In addition, 12 to 15 man-days of labor per hectare were required for applying the material over the 3-month period.

FUNGICIDAL TESTS IN 1946 AND 1947

Various fungicides were tested for their effectiveness against moldy rot in 1946 and 1947. Most of the testing experiments were made by applying the fungicide over an area of bark inoculated with a conidial suspension of the moldy rot fungus. The fungicides tested were white tar colloidal disinfectant, phenol coefficient 16+; Creolol coal tar disinfectant, phenol coefficient 2+; Puratized agricultural spray; Dithane D-14; and Goodrite (polyethylene polysulfide).

The experiments with these fungicides were made on the soft bark area of 4-year-old trees. In the first test, an area of soft bark approximately 3 by 6 inches was inoculated with a conidial suspension of *Ceratostomella fimbriata* and the fungicidal solutions were applied by thoroughly spraying the solution over the inoculated area with a knapsack sprayer. The fungicides were applied at different intervals after inoculation. The results of this test are summarized in table 3. The white tar and Dithane D-14 were the only effective fungicides in this test.

TABLE 3.—*Development of moldy rot on inoculated areas of herea bark treated with fungicides at different intervals after inoculation with Ceratostomella fimbriata*

Fungicide	Con- cen- tra- tion	Estimates of infection in relation to hours elapsing between inoculation and fungicidal treatment			
		2 hours	6 hours	10 hours	24 hours
White tar.....	1 : 20	None.....	None.....	None.....	None.
Puratized.....	1 : 500	Medium.....	Medium.....	Medium.....	Scanty.
Creolol.....	1 : 20	Abundant.....	Abundant.....	Abundant.....	Abundant.
Dithane D-14.....	1 : 50	None.....	None.....	None.....	None.
None (control).....		Abundant.....

To determine the protective value of the fungicides after application, another experiment was made in which the fungicides were applied to the bark and the inoculations made at different intervals thereafter. The results, summarized in table 4, indicate that insufficient fungicide is retained, even when the bark is thoroughly sprayed with the fungicidal solution, to prevent the development of the fungus, although some fungicidal effect could be noted in the treated trees in comparison with the control.

Other preliminary tests were made with Goodrite (p. l. p. s.) at a concentration of 1:400, in which the Goodrite was applied over inoculated areas. It was ineffective at this concentration and did not reduce the infection. A mixture of 2-percent wettable Sperguson and Goodrite also was ineffective. Results with Sperguson as a spray

indicated that it was effective against *Ceratostomella* only when the spores were germinating; that is, germinating spores were killed by a 2 percent solution, but ungerminated spores were not killed and apparently an insufficient quantity of Sperguson was retained by the bark to be effective.

TABLE 4.—*Development of moldy rot on areas of hevea bark inoculated with a conidial suspension of Ceratostomella fimbriata at different intervals after spraying the bark with fungicides*

Fungicide	Concentration	Estimates of infection in relation to hours elapsing between spraying and inoculation		
		2 hours	6 hours	24 hours
White tar.....	1:20	Medium....	Medium....	Medium.
Puritized.....	1:500	do.....	do.....	Do.
Dithane D-14.....	1:50	do.....	do.....	Do.
None (control).....	-----	Abundant..	Abundant..	Abundant.

Thus the results of these tests indicate that relatively little success may be expected in the treatment of moldy rot by the application of water solutions of fungicides and that the failure of the extensive field tests to do so is thus explained.

DISCUSSION OF DISEASE CONTROL STUDIES

The results reported in this circular emphasize the problems involved in the successful treatment of moldy rot of the tapping panels of hevea rubber trees and suggest the urgency of further investigations. Experimental treatment of panels with fungicidal preparations should be studied under plantation conditions that are nearer normal than the exceptionally poor conditions under which the present studies were made. Moldy rot development under conditions in southern Mexico was more severe than any reported from the Orient. Penetration below the tapping panel was a common occurrence in the Mexican plantings. Whether this difference is due to differences between the causal organisms from the two regions or to differences in environmental conditions and plantation practices affecting disease development is not known.

Although it appears that most hevea bark is susceptible to moldy rot, systematic testing of the numerous clones of hevea rubber trees seems warranted. If penetration of the fungus below the tapping cut, as observed in the Mexican plantings, is a common occurrence and not caused by exceptionally favorable conditions for disease development, the use of ordinary fungicidal preparations on the panels does not appear to be a promising approach to the problem.

The seriousness of moldy rot under some conditions and the inadequate control measures available make it urgent that every effort be made to prevent the introduction of the disease into new plantings. Whenever the fungus is found in new plantings serious attempts to

eradicate it are warranted. A suggested procedure for handling such cases in a new planting follows:

1. Stop tapping the infected tree and apply a fungicidal paste over the panel. The use of a strong fungicide, such as a 1-percent solution of Santobrite, might be recommended. Although this concentration will kill some of the bark tissue, it might be worth while if it kills the fungus immediately.
2. Keep infected trees out of tapping for 1 month.
3. Open a new panel at least 6 inches below the old one when tapping is resumed on infected trees after they have been out of tapping for 1 month.
4. Observe closely for any reappearance of moldy rot on the new panel.
5. Use a strong disinfectant (such as 1-percent Santobrite) on tapping knives before beginning to tap a new planting. If cases of moldy rot appear, dip tapping knives in the disinfectant after each tree is tapped.

RELATION OF CERATOSTOMELLA FIMBRIATA TO A BARK CANCKER

A bark cancker arising from injured areas, such as old tapping wounds, on the trunk and progressing up the tree was observed in the old hevea seedling trees in Mexico. More than 50 trees in a planting of approximately 1,200 were affected. Varying degrees of cracking of the bark with subsequent flow of latex on infected trees is illustrated in figure 6. The canckers were visibly active only during the rainy season. When a tangential section of the bark of an infected tree was cut with a sharp machete, a rather sharp line of demarcation was observed between the healthy and diseased tissue toward the upper part of the cancker. The infected tissue next to the healthy tissue had a greenish-black discoloration similar to that caused by *Ceratostomella fimbriata* on hevea bark.

At first the cancker appeared to be similar to that caused by *Phytophthora* sp. *Phytophthora*, however, was never found associated with this cancker, although repeated examinations of the canckers and attempts to isolate it were made during the rainy season.

Numerous isolations were made from the infected tissue of trees showing the canckers, and *Ceratostomella fimbriata* was among the most common fungi obtained. Several other fungi, including *Fusarium* sp., *Pestalozzia* sp., *Diplodia* sp., and several sterile forms (mostly producing dark-colored mycelium on malt extract agar) were obtained. Attempts to reproduce the cancker with isolates obtained from the infected trees were not successful. In one series of inoculations with *C. fimbriata* on 5-year-old trees in early 1947, however, the characteristic cracking of the bark with subsequent oozing of latex was observed (fig. 7). The fact that *C. fimbriata* is commonly isolated from these canckers in tissue bordering the healthy tissue and the characteristic cracking of the bark resulting from inoculations, shown in figure 7, suggest that *C. fimbriata* might be the causal organism of this cancker.



FIGURE 6.—Seedling tree of *Hevea brasiliensis* with a bark canker that has progressed up the trunk. This condition invariably originated from old tapping wounds or other bark injuries.

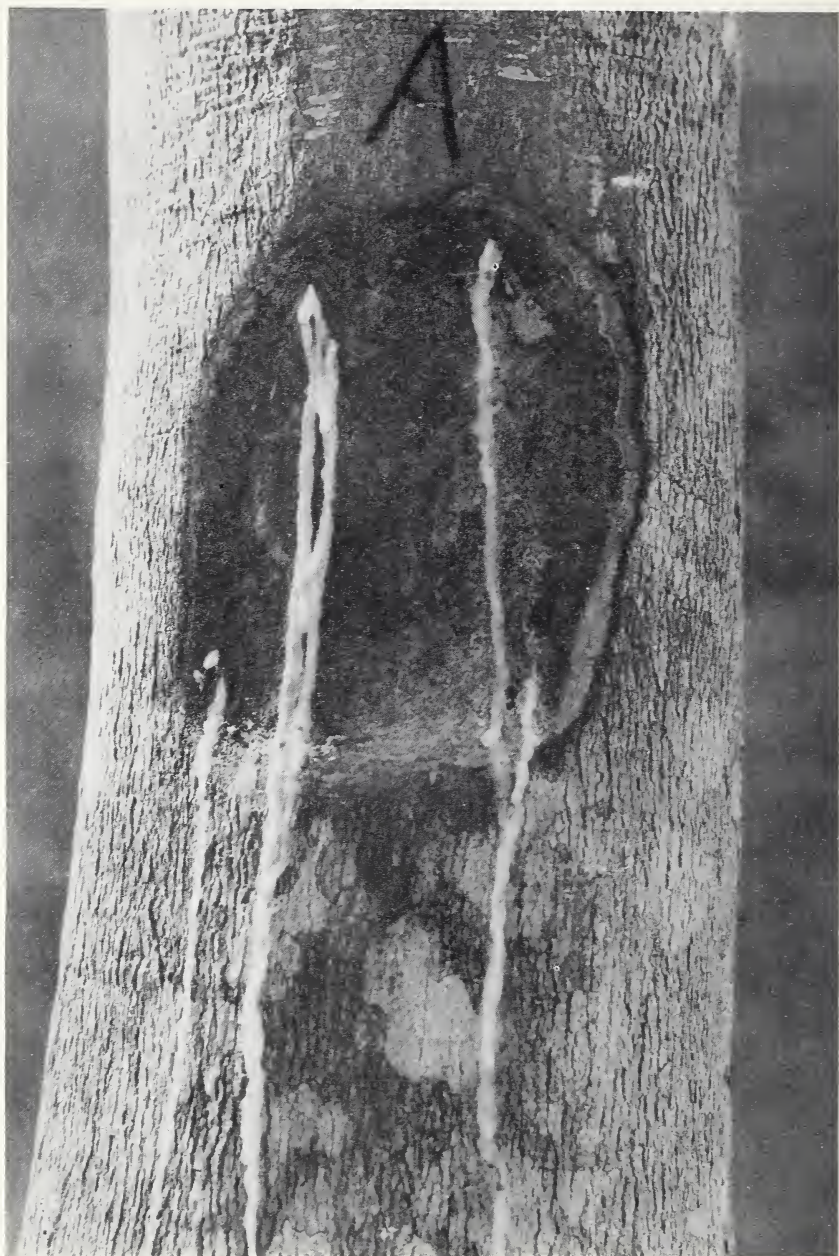


FIGURE 7.—A 5-year-old seedling tree of *Hevea brasiliensis* that had been inoculated 10 days previously with a conidial suspension of *Ceratostomella fimbriata* in the soft bark area, showing the cracked bark and the latex that has flowed from it.

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